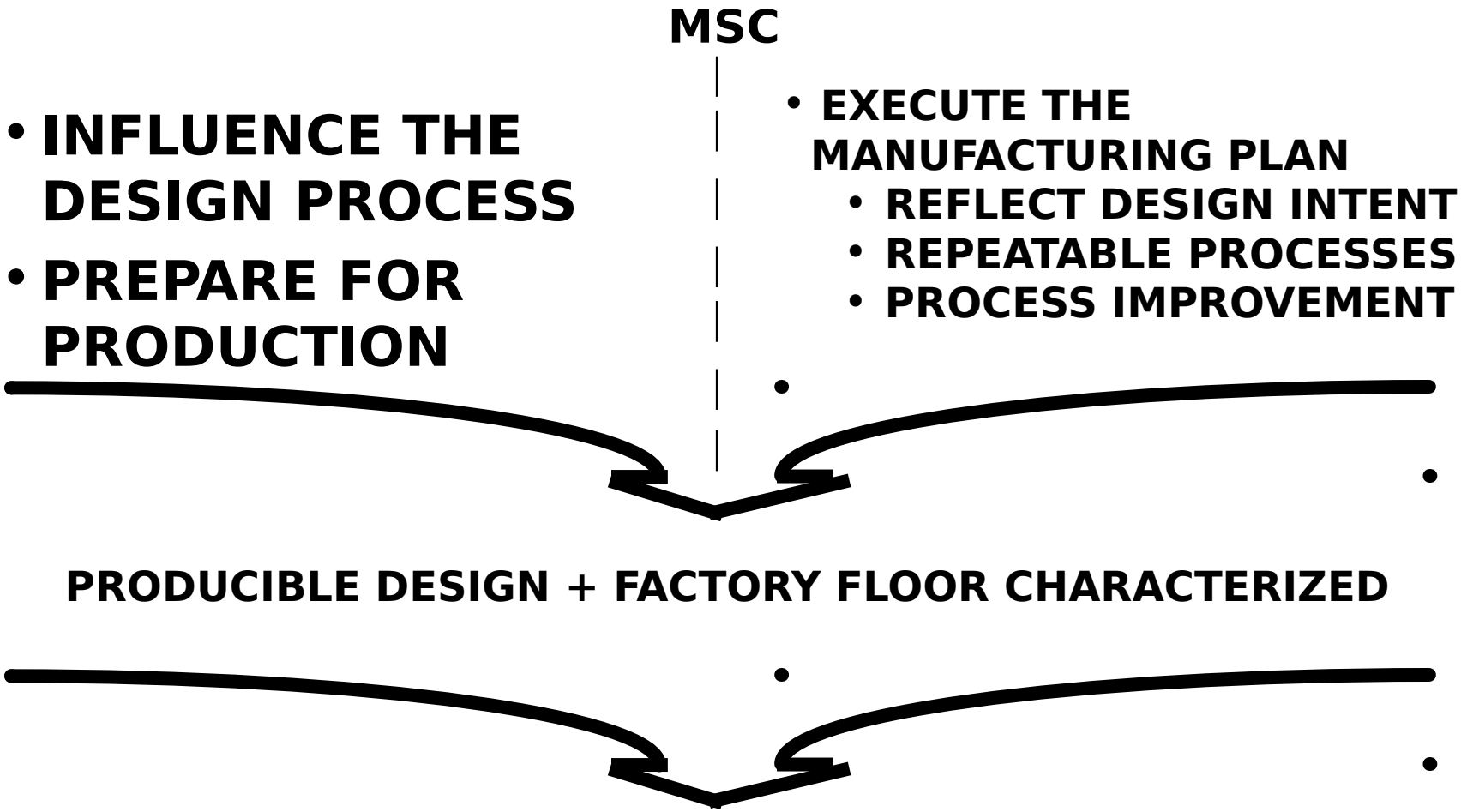
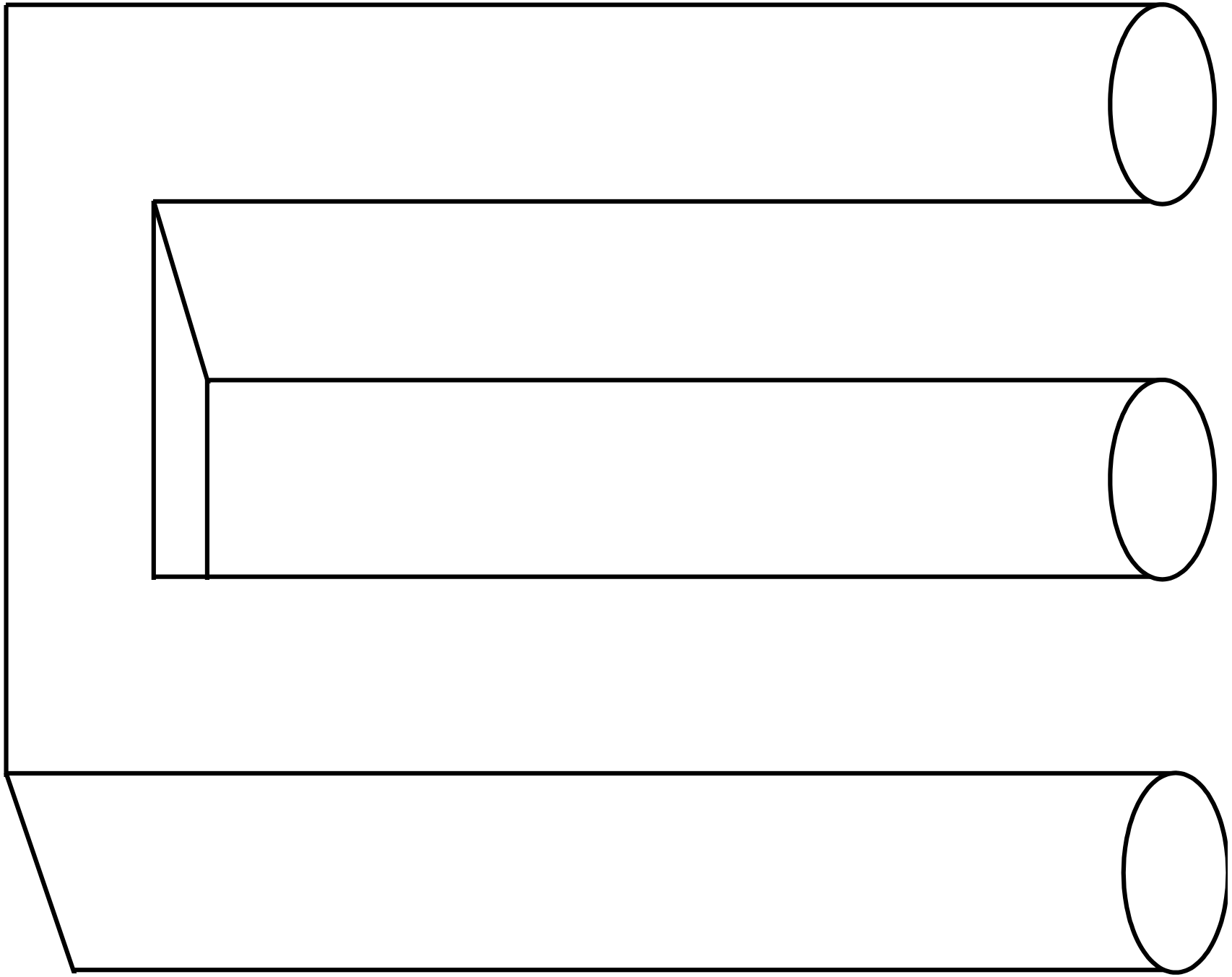
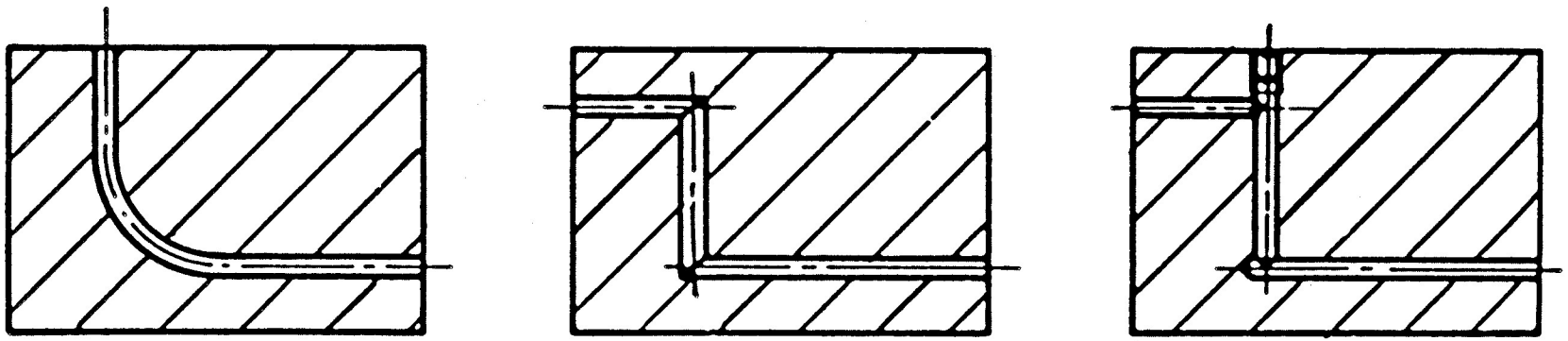
# Design-Build

## *(Producibility)*

# THE ROLE OF MANUFACTURING







# Technical Impacts of Mfg

- **A design constraint; can design be physically realized?**
- **A risk driver; can mfg meet cost and schedule?**
- **A set of enabling/critical technologies; will required processes be available, capable (Q), and adequate (capacity)? How well characterized are the processes and materials?**
- **Design phase obligates at least 80% of LCC;**
  **design establishes materials, tolerances, tooling, derived production processes and required employee skills.**

**What functional group(s) should have the most responsibility for producibility?**

# Production Issues
## Risks And Concerns

- **Unstable Requirements & Engineering Changes**
- **Unstable Production Rates & Quantities**
- **Insufficient Process Proofing of New Processes**
- **Insufficient Materials Characterization**
- **Variability of Processes and Components**
- **Producibility**
- **Real Production Readiness Reviews of Value**
- **Changes in Proven Materials, Processes, Subcontractors, Vendors & Components**
- **Configuration Management**
- **Subcontractor Management**
- **Special Tooling (ST) & Test Equipment (STE)**
- **Special Processes; welding and composites**

# Insufficient Materials Characterization & Process Proofing

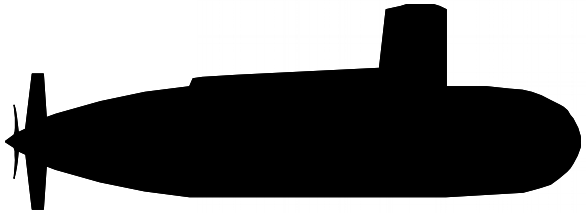
**M1 Tank:**

**Unable To Cut Armor Plate To Net Shape. Process Not Tested At Production Sizes And Rates.**

**C-17 Aircraft:**

**Aluminum-Lithium Cracking. Anisotropy Not Detected.**

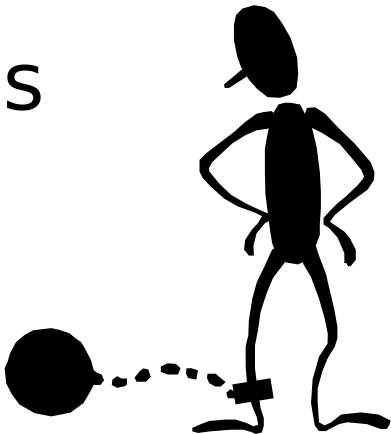
**Seawolf Submarine:**



**HY100 Weld Cracking. Undetected Interaction Between Filler Wire Carbon Equivalent And Weld Preheat due to process parameter extrapolation.**

# PRODUCIBILITY

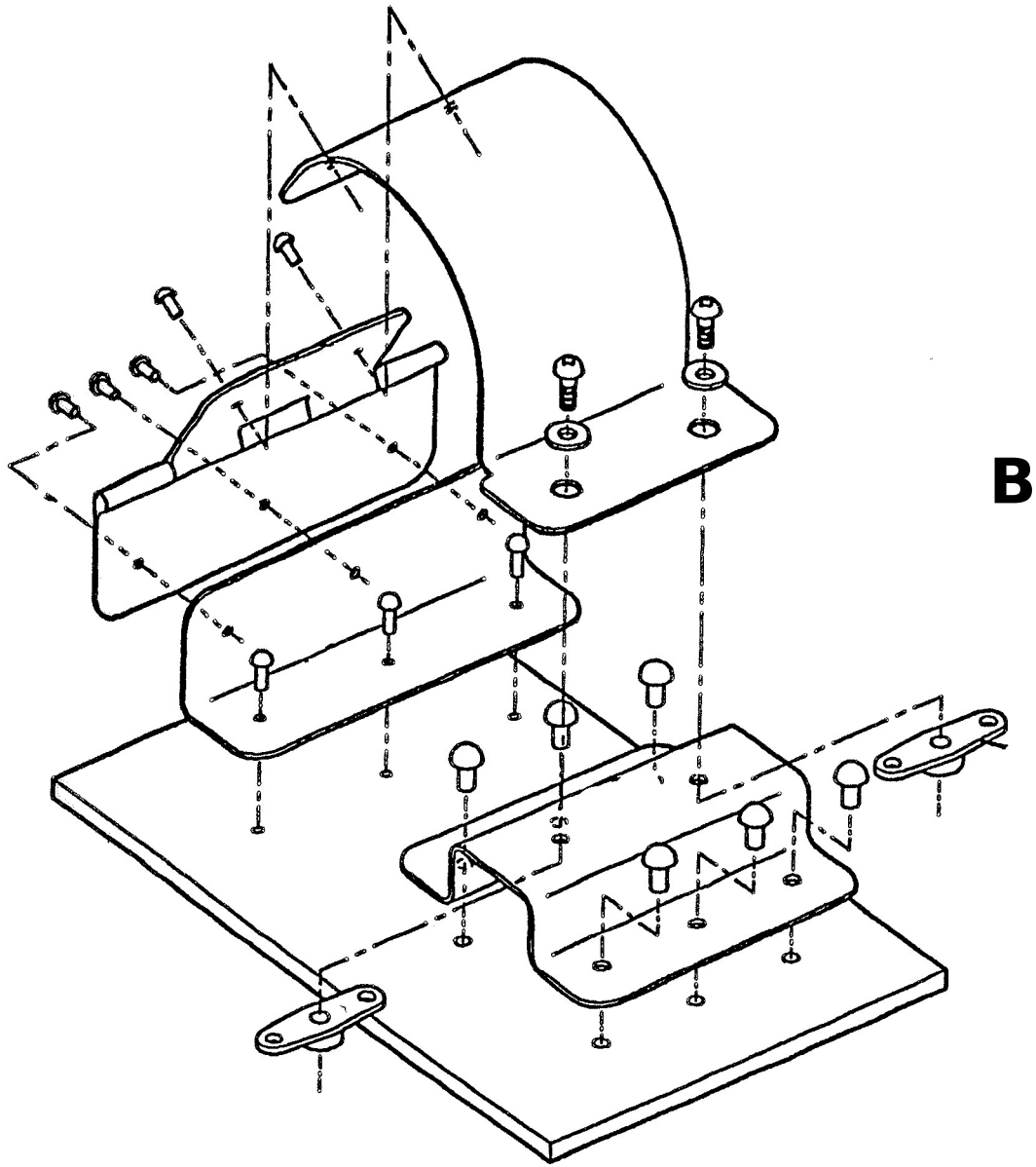
- A measure of the relative ease of production.
- Is the primary responsibility of the SE/design functions w/strong input from mfg (remember lean 3P methodology).
- Required by the DoD 5000 Series.
- Can be measured – how?
- In many design situations requires a trade-off.



# Product & Process Design for Producibility (DFSS)

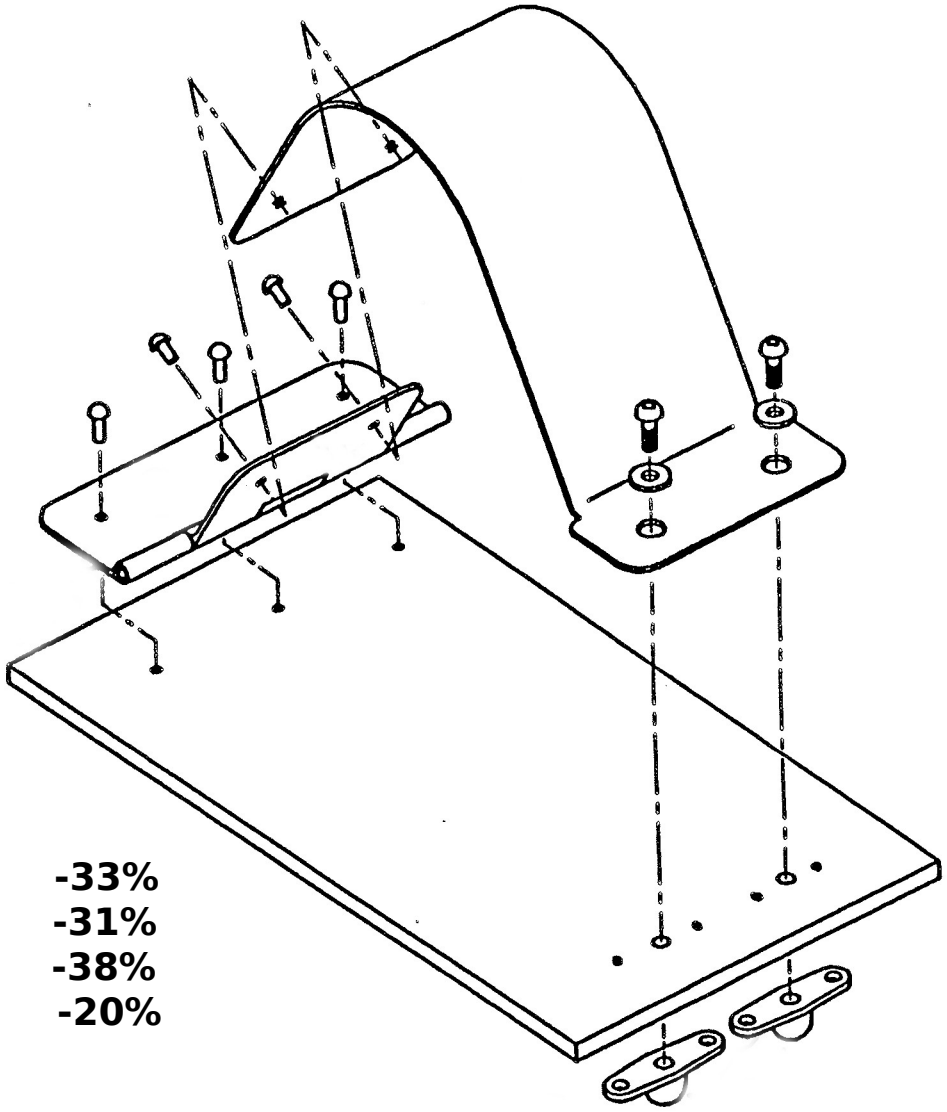
- **Reduce the number of times that people and machines touch the product**
- **Reduce unnecessary process steps**
- **Design workspaces and tooling for unobstructed access and vision**
- **Minimize the total number and types of parts**
- **Use standard components**
- **Design multifunctional/multiple use parts**
- **Avoid separate fasteners**
- **Maximize compliance in assembly. Make parts easy to align and locate.**
- **Minimize adjustments and re-orientations during fabrication and assembly**
- **Single direction assembly**
- **Ease the handling of parts and tools (waist high vs. overhead)**
- **Minimize special materials and processes**
- **Use open standards**
- **Ensure new materials are properly and completely characterized**
- **Ensure new processes are proven at full-rates in production representative conditions**
- **Develop trade-off data for different volumes, materials, processes and related tooling**
- **Develop quantitative measures of process capability (Cp & Cpk) and maintain process control**

# F-18 E/F Ejection Seat Bailout Oxygen Bottle Bracket



**BEFORE**

**AFTER**



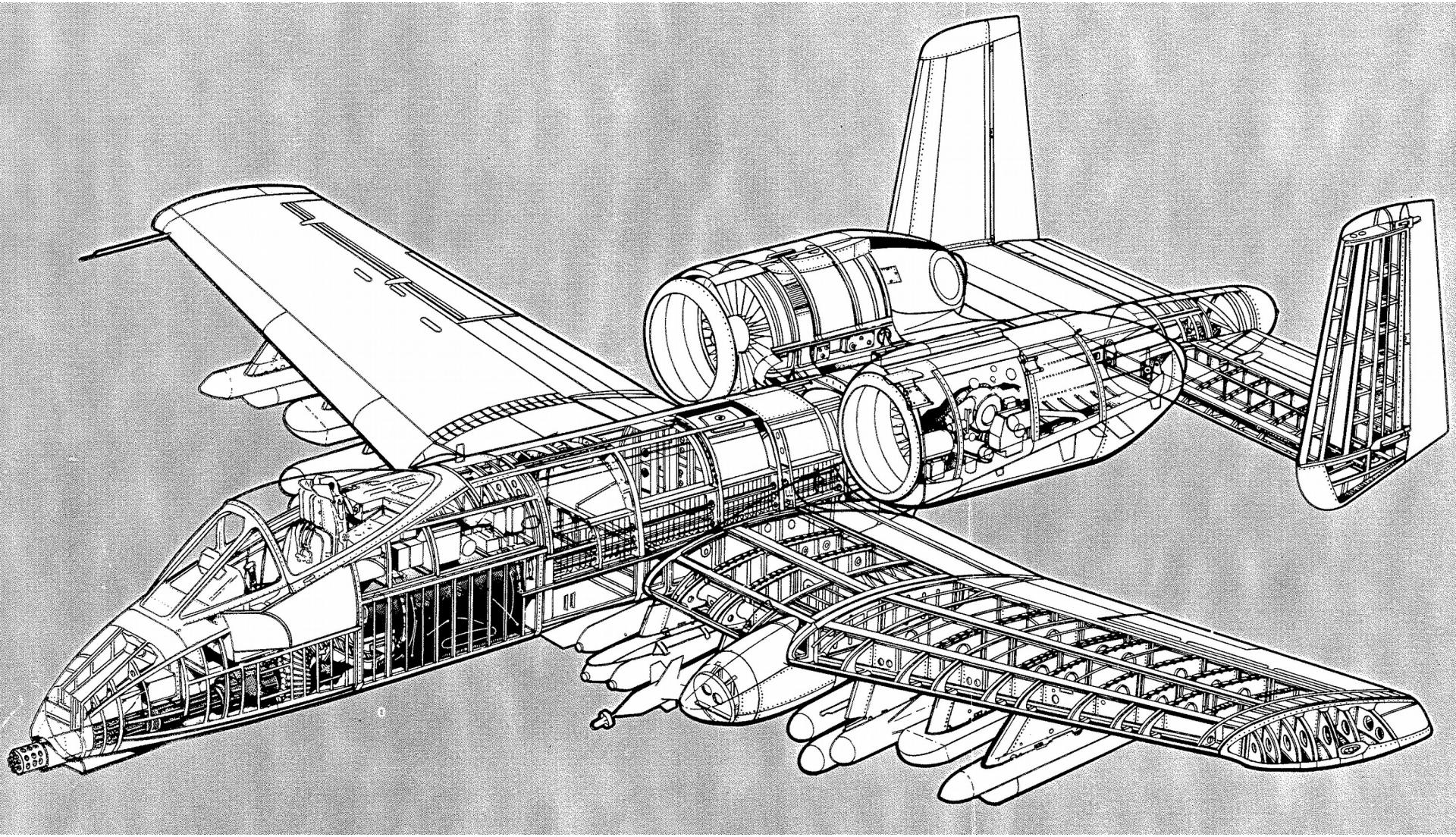
| | |
|---|---|
| **Number of parts** | **-33%** |
| **Number of operations** | **-31%** |
| **Number of fasteners** | **-38%** |
| **Assembly time** | **-20%** |

# Every Part Creates Overhead $

- **Every part, no matter how small, has significant O/H costs:**
  - **Ordering**
  - **Receiving**
  - **Stocking**
  - **Delivering to Point of Use**
  - **Reworking**
  - **Reordering**
  - **Maintaining Spares**
  - **Writing & Updating Technical Manuals**
  - **Supplying to Field Service**
  - **Packaging & Shipping**
- **Multiply this overhead cost by the number of times it is repeated during the life cycle of a product this equals the total cost of the part.**

# Producible Systems

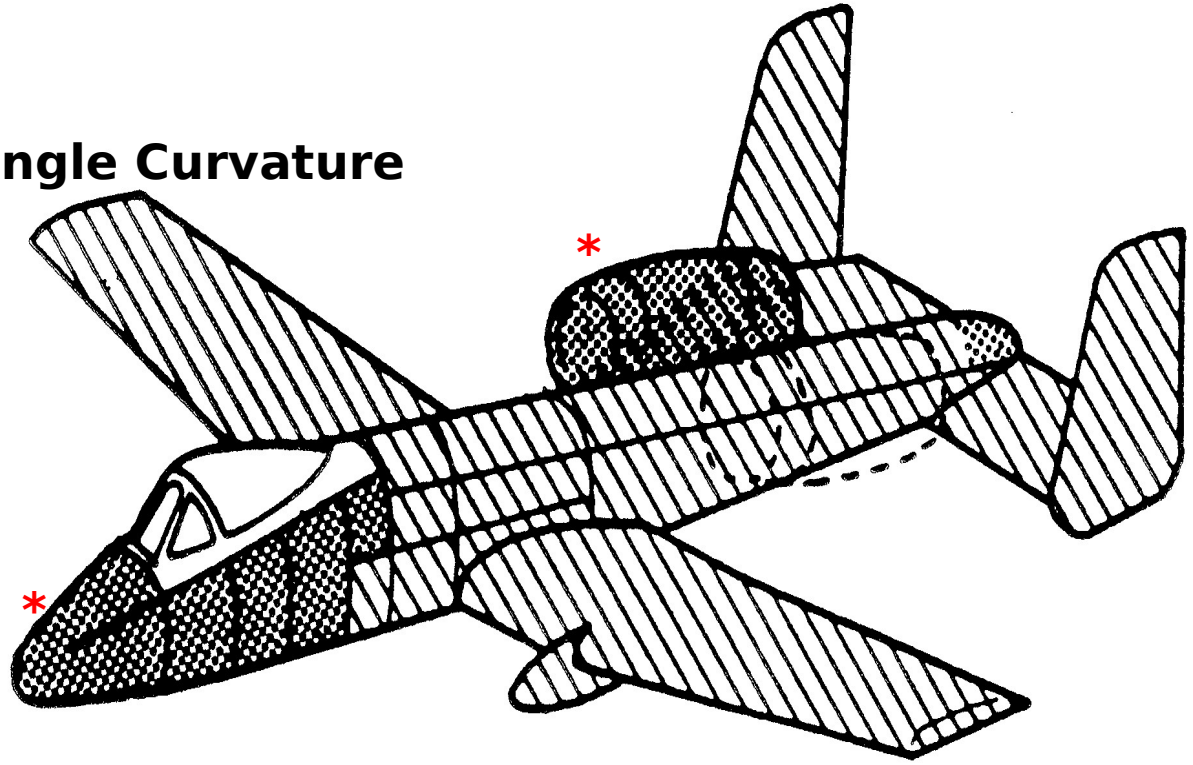
- Model T
- Liberty Ships
- Higgins Boats
- Soviet AK-47
- Soviet RPG
- Soviet T-34 Tank
- F-16
- A-10



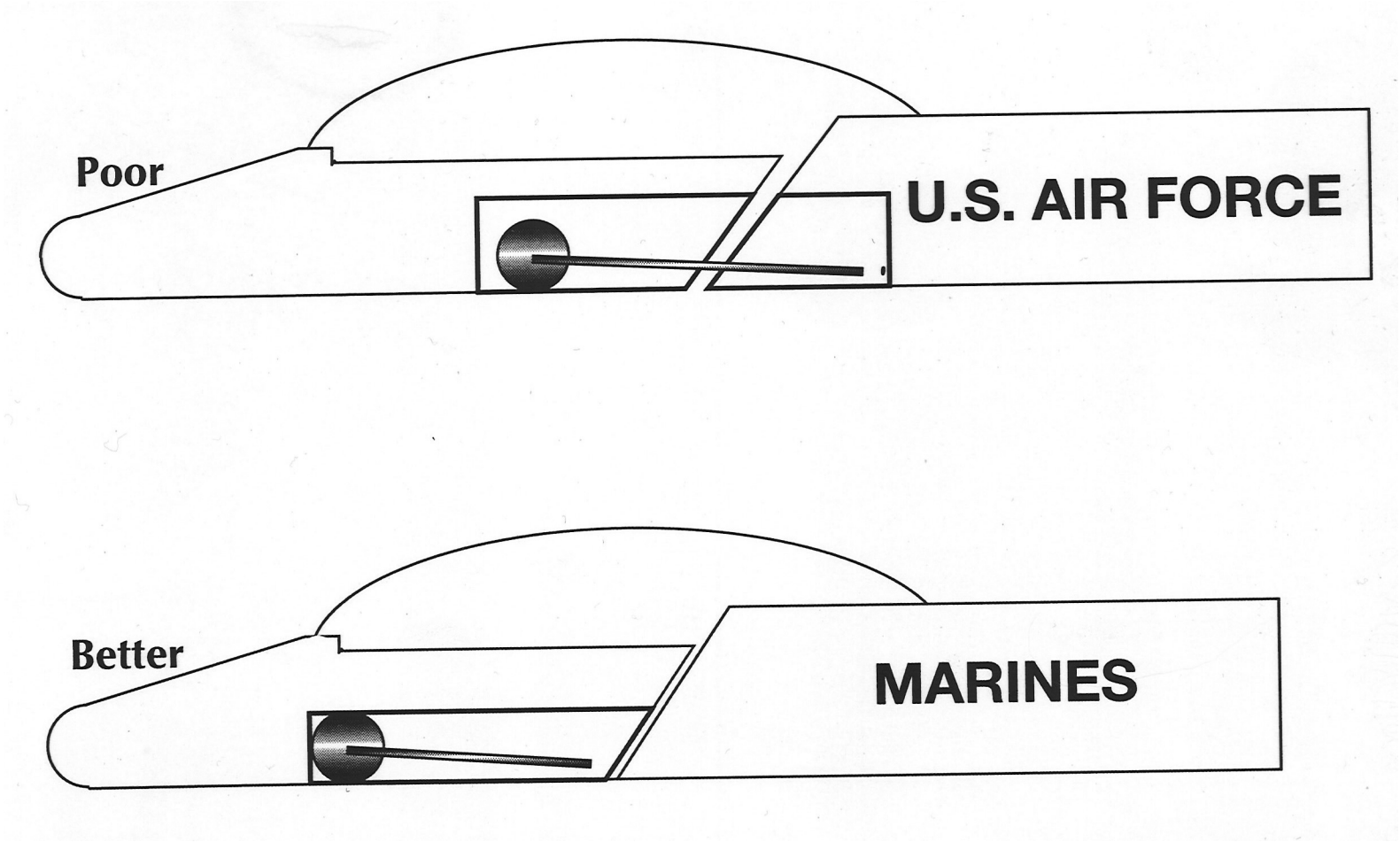
A-

me 95% aluminum by weight
rivets only on forward 1/3 of airframe
ized compound curvature – minimizes need for special tooling
nal landing gear pods – simplifies load paths and internal structure
ant chord wind box – minimum machining with emphasis on 3 axis mac
y use of extrusions – minimum machining
ardization of empennage components – no left-hand and right-hand pa

\\\\\\ Single Curvature



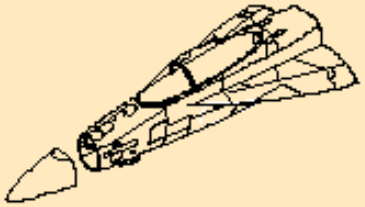

* Compound curvature of tub and nacelles only. The rest of the fuselage is single (developable) curvature.




**Location of a subassembly break can increase interface complexity, increase assembly time and decrease worker access during assembly.**

# Design for Manufacturing Has Reduced F/A-18E/F Parts Count

## Forward Fuselage and Equipment



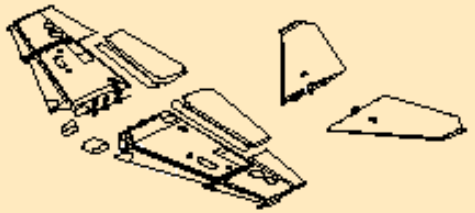
C/D Parts
5,907

E/F Parts
4,046

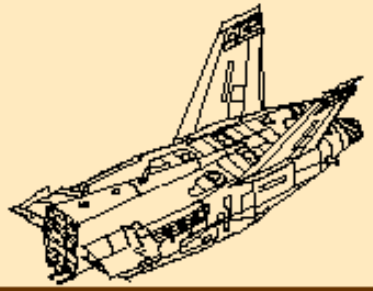
## Wings and Horizontal Tails

C/D Parts
1,774

E/F Parts
1,268



## Center/Aft Fuselage, Vertical Tails and Systems



C/D Parts
5,500

E/F Parts
3,494

**Total**

| C/D Parts | E/F Parts |
|---|---|
| 14,104 | 8,099 |

***E/F 25% Larger and 42% Fewer Parts Than C/D***

# Critical and Key Characteristics

There is some confusion over the two terms – ask if you are not sure

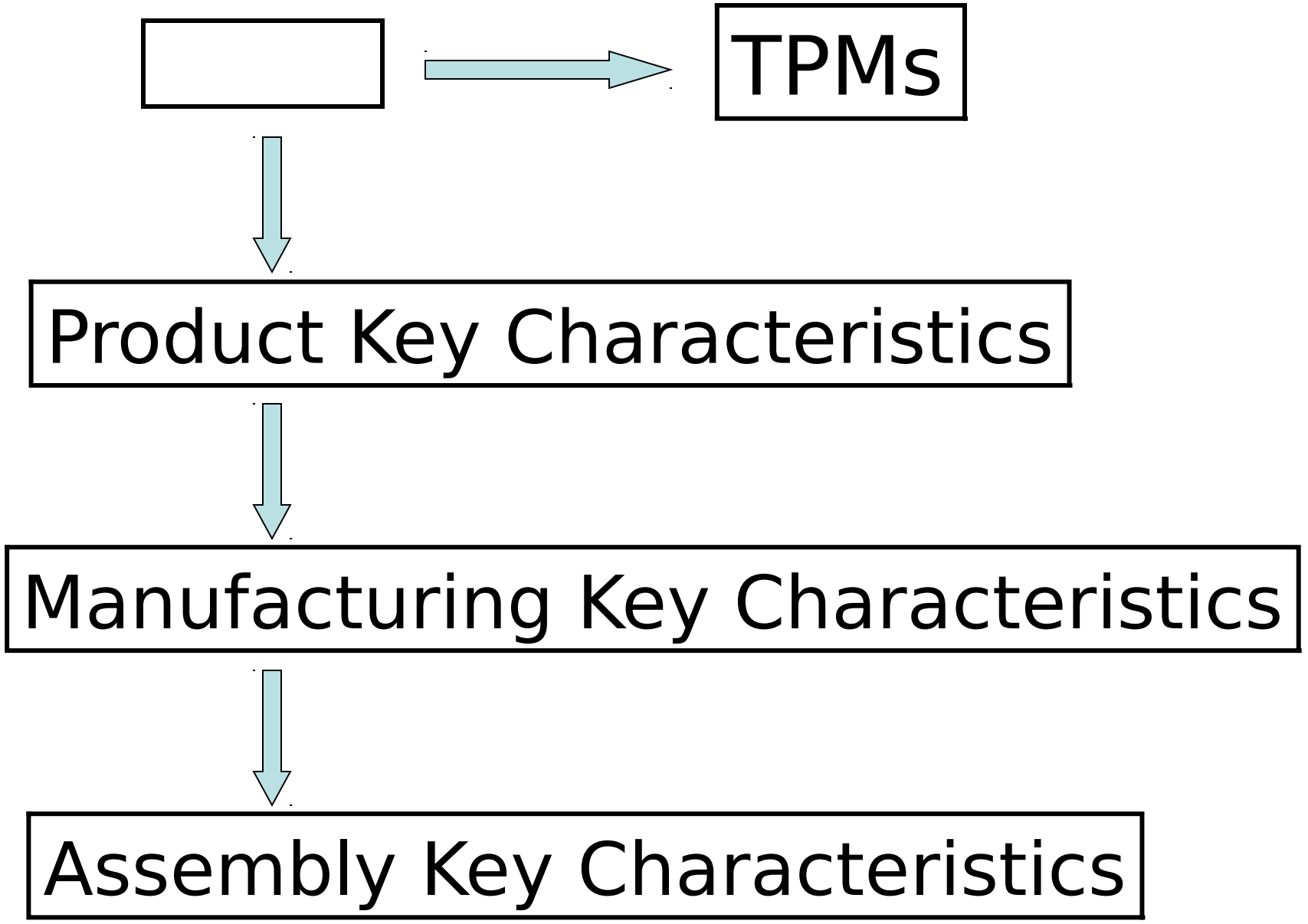
**Critical Characteristic = Critical Safety Characteristic = Flight Safety Characteristic:**

Any feature throughout the lifecycle that if nonconforming, missing or degraded may cause the failure or malfunction of a Critical Safety Item. Critical Characteristics address product safety issues.

# Key Characteristic

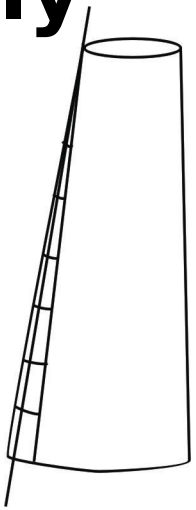
A feature of a material, process or part/assemblies whose variation within the specified tolerance has a significant influence on product fit, performance, service life or manufacturability.

KCs identify opportunities for improvement though the management of variation. KCs are usually managed at > 1.33 Cpk. This is an arbitrary number.


TPMs
Product Key Characteristics
Manufacturing Key Characteristics
Assembly Key Characteristics

# Boeing 777 Rudder Assembly

**Critical & Key:**
**Hinge attach points alignment**



**Critical & Key:**
**Contour of surface**

**Hinge Attach Points Alignment Key Feature & Mfg Characteristics:**

- **Rib Width**
- **Spar Width**
- **Flange Thickness**
- **Hinge Fitting Hole Location**
- **Hinge Fitting Flatness**

# Production Readiness Reviews

- Incremental, proactive, preventative reviews spread over development
- Identify Risks, issues, and opportunities Early
- Assess Capability to deliver on time, within cost
- Assess actual Performance (develop metrics)
- Assess Effectiveness of corrective actions
- Measure performance and continuous improvement
- Use your DCMA/CAS resources

# Production Readiness Reviews

- Get a Charter that the PMO and Contractor Understand
- Coordinate with DCMA/CAS
- Establish Areas of Assessment
  - Producibility Problems & Opportunities
  - Engineering changes/Design stability
  - Cost of scrap, rework and repair
  - Sub-contractor performance
  - Cost and Delivery performance
  - Manufacturing Process Control
  - Status of corrective actions
  - Tooling status
- Develop Metrics
- Ask questions, touch things, speak to shop floor workers
  - PRRs are a contact sport
  - Go to the Gemba

# PRR Metrics Summary

1. Design Maturity? TRL?
2. Is as-built feasible? How producible is design?
3. Manufacturing processes are available, proven, adequate capacity, capable and in-control. MRL?
4. Facilities are available and adequate.
5. Suppliers are available, capable and reliable.
6. Risk areas and proposed mitigation?

**There is no formal requirement for production plans or production related CDRLs. The PM does have to meet requirements for cost, schedule,performance, quality, producibility, validated production processes, adequate production facilities and production-representative test items. Manufacturing issues should be included in the Risk**

# Generic Production Plan

# Generic Production Plan

I. Production Management
- Organization
- Functional Responsibilities
- Master Schedule
- Production Control
- Change Management
- Product Data Management/Digital Data Exchange/Records

II. Manpower Plan
- Manpower Level
- Skills Availability
- Training

III. Industrial Facilities
- Description
- Layouts
- Shop Floor Control

IV. Surge and Mobilization Capacity Assessment - ICA Issues

# Generic Production Plan

V. Manufacturer Risk Assessment
- Design Stability Assessment
- Process Proofing/Materials Characterization
- Key Processes
- Producibility Issues

VI. Capital Investment Plan

VII. Producibility Program
- Design & Manufacturing Integration (IPT Process)
- Key Characteristics Plan
- Trade-off Process
- Sub-contractor Producibility

VIII. Materials Management
- Make vs Buy
- Long - Lead
- Inventory Control/MRP

IX. Sub-contractor/Supplier Management
- Communications & Change Control

# Generic Production Plan

**X. Manufacturing Methods & Production Flow**
- **Process Planning**
- **Process Flow, Sequencing and Routing**
- **Work Instruction Process**
- **Computer Simulations**

**XI. Quality Assurance**
- **ISO 9000/AS 9100: compliance or registration**
- **Process Control Methods**
- **AQS Techniques**
- **Process Improvement/Variation Reduction**
- **Corrective Action Process/Non-Conforming Material**
- **Cost of scrap, rework or repair**

**XII. Metrology**
- **Facility & Equipment**
- **Standards**

**XIII. Special Tooling & Test Equipment**

**XIV. Environmental Compliance, Scrap Management & Reclamation**

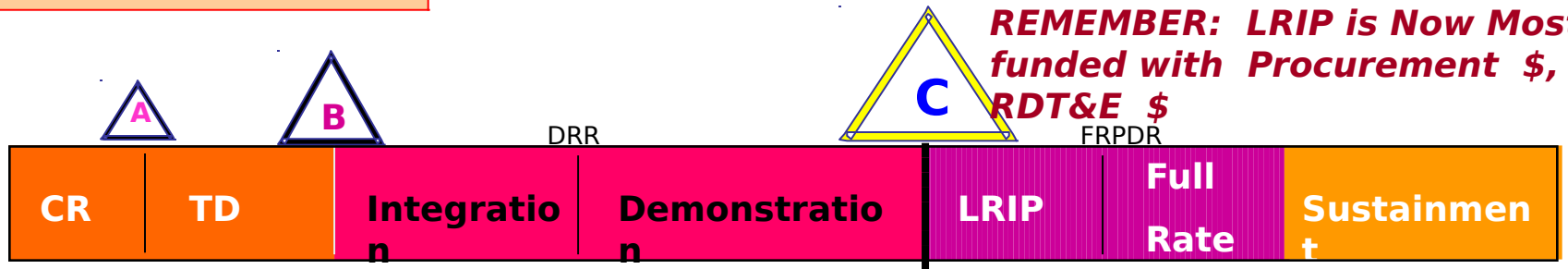
**XV. Internal Audits & Reviews**

**XVI. Labor Relations**

# The Role of Manufacturing in the Acquisition Process

**CURRENT DOD 5000 PROCESS**

***REMEMBER: LRIP is Now Mostly funded with Procurement $, Not RDT&E $***




**RDT&E**
- **Influence the Design Process**
- **Prepare for Production**

**PRODUCTION**
- **Execute the Manufacturing Plan**
- **Reflect Design Intent**
- **Repeatable Processes**
- **Continuous Process Improvement**

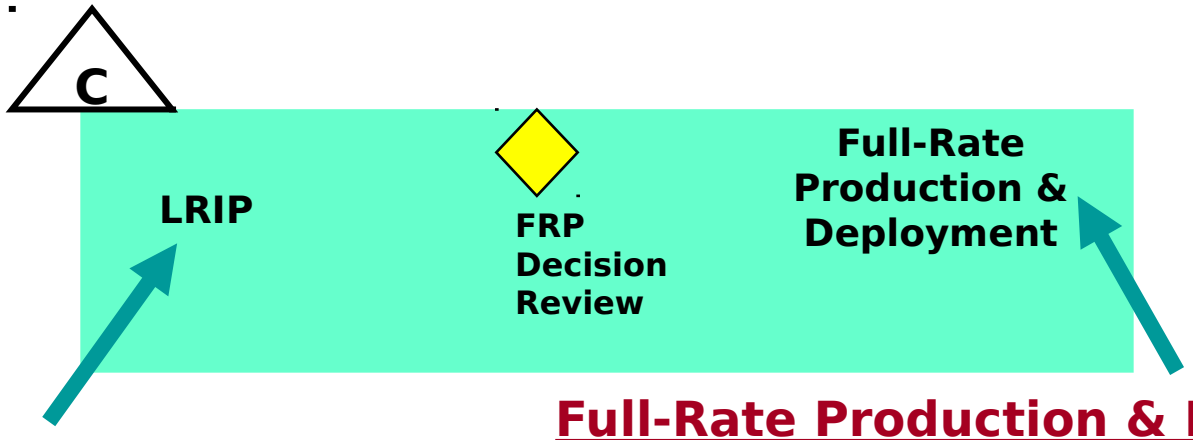
**Production Readiness Reviews, PRRs (Minimum recommended number)**

**By Milestone C, Need to have Proven you have:**
**Producible Designs + Factory Floor Characterized**
**and per**
**DoDI 5000.2: No significant**

**Net Result:**
- **Uniform, Defect Free Product**
- **Consistent Performance**
- **Lower Cost**

# Production & Deployment

**DODI 5000.2, 12 May 2003 and**
**Defense Acquisition Guidebook, 19 Oct 04**




## LRIP

**To Enter**: System matured for production; Industrial Capabilities Reasonably Available (to exit SDD); **NO SIGNIFICANT MANUFACTURING RISKS**.

Major Activities: Low-rate initial production (provides test assets for IOT&E, initial production base, & ramp-up to full rate production); IOT&E; LFT&E of production-representative articles. Establish full manufacturing capability.

## Full-Rate Production & Deployment

**To Enter**: Beyond LRIP (ACAT I) and LFT&E reports (covered systems) submitted to Congress. Demonstrated control of manufacturing and other critical processes. **REQUIRES STABLE DESIGN, PROVEN MANUFACTURING PROCESSES AND RESOURCES TO SUPPORT PRODUCTION**.

**Major Activities**: Full rate production. Deploy system. Start support.

**Exit**: Full operational capability; deployment complete.